Naval Research Laboratory

Washington, DC 20375-5320

NRL/MR/6180--01-8557

DC-ARM Organizational Procedures and Manning for Smart Controller

CAPT ROBERT K. BARR, USN (RET.)

Ship Survivability Technology
Triangle, VA

FREDERICK W. WILLIAMS

Navy Technology Center for Safety and Survivability
Chemistry Division

June 25, 2001

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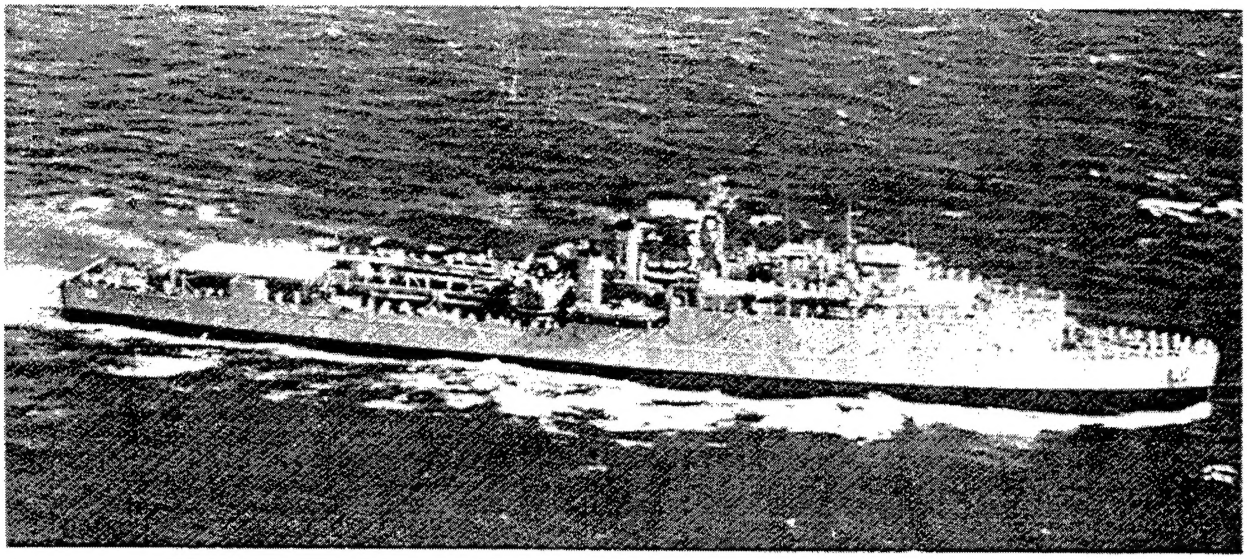

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (*Leave Blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	June 25, 2001	Interim FY 2001

4. TITLE AND SUBTITLE

DC-ARM Organizational Procedures and Manning for Smart Controller

5. FUNDING NUMBERS

PE - 603508N

6. AUTHOR(S)

CAPT Robert K. Barr, USN (Ret.)* and Frederick W. Williams

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Research Laboratory, Code 6180
4555 Overlook Avenue, SW
Washington, DC 20375-5320

8. PERFORMING ORGANIZATION REPORT NUMBER

NRL/MR/6180--01-8557

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Office of Naval Research
800 N Quincy Street
Arlington, VA 22217-5660

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

*Ship Survivability Technology, Triangle, VA 22172-1505

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

A proposed manning is set forth in this document to accompany the Applied Research Laboratory (Pennsylvania State)/Ship Survivability Technology's DC-ARM Intelligent Controller System (ICS) that is to be demonstrated aboard the ex-USS *Shadwell* in September 2001. This manning requirement is relative to varying environments that exist in a ship's operational cycle, the ICS hardware, the key system's damage control data processing elements, and the manned stations' data displays.

14. SUBJECT TERMS

Damage control
Ships
Fire
Flooding
Automation
Smart controller

15. NUMBER OF PAGES

17

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std 239-18
298-102

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DC-ARM ORGANIZATIONAL PROCEDURES AND MANNING FOR SMART CONTROLLER

1.0 PURPOSE

To describe the organization, procedures and manning requirements for a modern U.S. Navy combatant ship, designed for Damage Control (DC) manning reductions, through automated application of an automated Supervisory Control System (SCS).

This description profiles the Applied Research Laboratory (Pennsylvania State)/Ship Survivability Technology (ARL/SST) DC-ARM Intelligent Controller System (ICS) automation capability [1,2], designed to support the DC manning reduction, and offer a supporting organizational structure. This structure discusses manning requirements relative to varying environments, which exist in a ship's operational cycle, the ICS hardware, the key system's DC data processing elements and the manned stations' data displays.

The ICS operational procedures outline the different manning requirements, personnel duties and responsibilities during various conditions of readiness experienced throughout a combatant's life cycle. This description of personnel duties leads to establishment of a calculated potential manning complement of DC personnel with consideration for variances resulting from differences in the watch section arrangement. In view of the obvious impact manning reduction will have on a ship's routine maintenance, a discussion of that impact includes an option for solution.

2.0 ICS COMPONENT DESCRIPTION

The ARL/SST DC-ARM ICS is an autonomous damage control casualty management system based on a previously proven Navy weapons control technology [3], which has now been developed for application in automated damage control. This application is intended for reduction of the manpower-intensive effort currently required for control of weapons-induced casualties [4]. As currently designed, the DC-ARM Program [5] has the potential for supporting a major reduction in DC personnel.

The Intelligent Controller (IC) is a computer program that analyzes sensor data and generates responses appropriate for carrying out an implicitly stated mission, in this case, damage control. The responses are in the form of commands and communications to systems external to a particular IC. These systems may be other ICs, conventional control systems, effectors or human collaborators. The IC is the key component for the ICS in the form of any given number of Deck/Zone controllers, referred to as Deck (or Zone) ICs and a supervisory IC. The Supervisory IC is a single IC serving as a "coordinator" for the Deck/Zone ICs. Among other functions, the Supervisory IC mediates all communications between components of the ICS and between the ICs and a human observer, via an electronic display of Graphical User Interfaces (GUI).

Manuscript approved May 10, 2001.

The hierarchical interacting system that constitutes the ICS for performance of damage control, communicates via an external data network [6] providing sensor data input to the Deck/Zone ICs. In turn, the IC-processed data that result in orders to the various conventional control systems, or activators, are passed over the same network. As corrective actions occur in the affected space(s), the monitoring sensors will relate that action to the ICS; thereby, providing constant feedback on progress of the ordered actions. All ICs on the data network will be capable of monitoring all available network data. In the event failure occurs in one or more of the ICs, the hierarchical interacting system will provide for assignment of data processing responsibilities to another, or other ICs as may be required (Fig. 1).

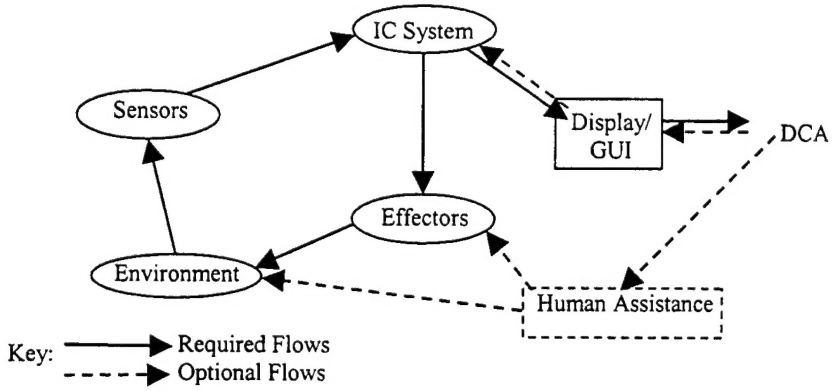

Figure 1. Closed-Loop Intelligent Controller System

3.0 AUTOMATED SUPPORT FOR REDUCED MANNING

The ARL/SST DC-ARM SCS automation is intended to mimic the human process of damage control data collection, perceptions of what is occurring, development of a proper response and automated commands to the proper system activators to contain damage in the primary damage area. To achieve this objective, the ICs in the system are designed to accept messages from installed sensor systems or humans. The messages may be data from either another IC or a human collaborator; such as a watch stander supervisor or the damage control officer.

Within the IC design are two modules referred to as "Perception" and "Response". The Perception module creates an internal representation of the external world, or situation awareness relevant to the ICs sensor data stream input. This representation serves as the basis for generation of operational responses by the Response module. The Response module, utilizing the situational awareness provided by the Perception module, conducts an operational assessment of that situation, plans a course of action, develops a plan of execution, then sends out effector commands, orders or queries and advisories to other ICs in the ICS to effectively contain the damage (Fig. 2).

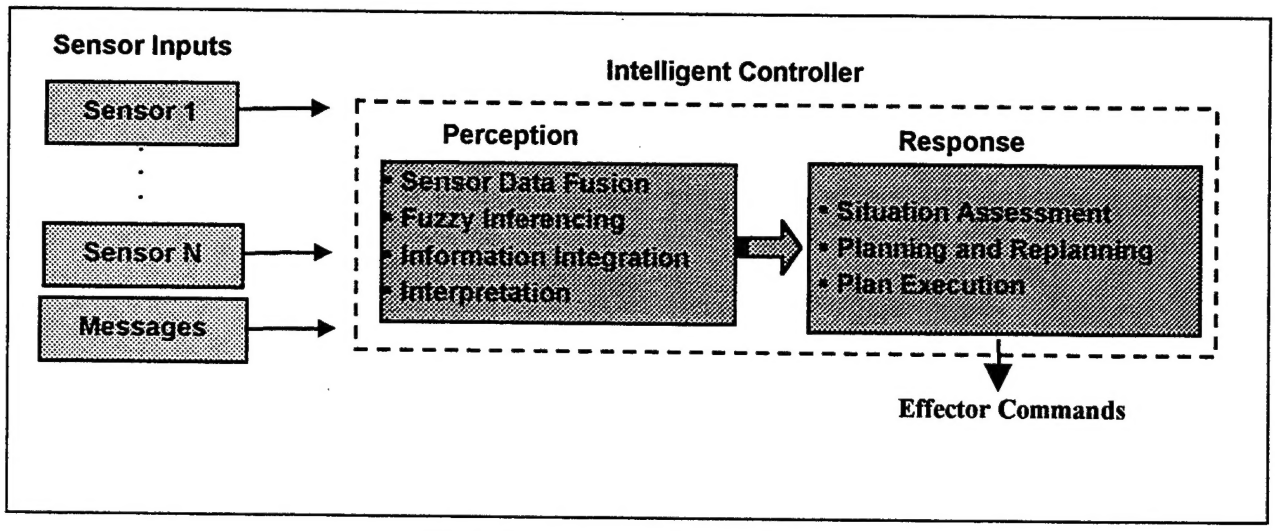

Figure 2. Intelligent Controller

Depending on the particular ship design, the ICS design could include any numbers of Deck/Zones in the ICS relative to the subdivision and deck arrangement of the ship. The unique aspect of the individual ICs is that each is programmed to accept the ship-specific configuration files required to effectively exercise control over its' area of responsibility, as well as respond to the supervisory controller. Within the individual ship design, there is a need for a supervising control station that will interface with all the inter-connected Decks/Zones in the ICs. While each of the ICs is capable of exercising independent control over its' area of responsibility and associated system activators, in the event of a casualty to the SCS, there should be an alternate station of equal capability. It is also considered the ARL/SST DC-ARM ICS would be co-located with all other HM&E monitoring and control components, although not necessarily incorporated within those components (Fig. 3).

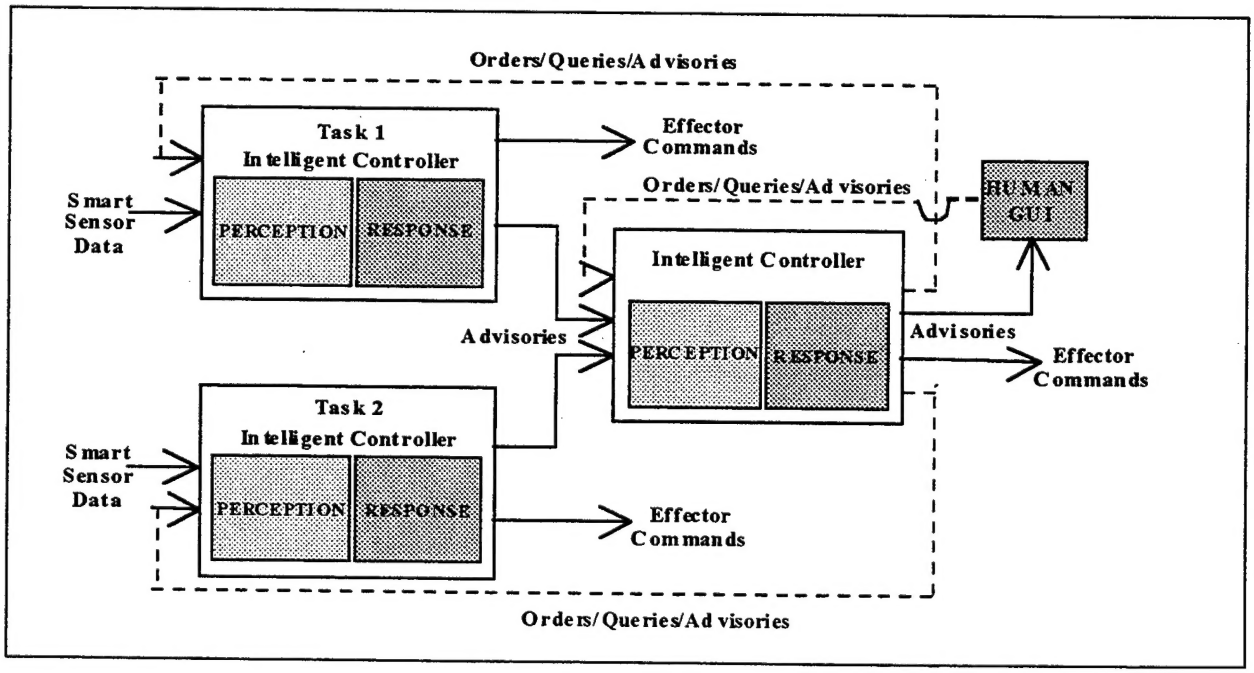

Figure 3. Intelligent Controller System Modules and Interfaces

Because of the critical nature of the ICS, it is essential the system, including sensor data transmission, data processing and activator control, be supported by an Uninterruptable Power Supply (UPS). It is envisioned the ICS will be designated as a vital system, relative to primary and alternate electrical power supply. Also, provisions for UPS are necessary to ensure the ability to exercise system control in the event all other HM&E electrical power producing systems are in a failure mode, either temporarily or for an extended period.

The ICS will be provided with a series of three GUI's to monitor the continuous flow of ship status information including activity within the individual Decks'/Zones' status of supporting DC Systems and individual compartment level details. The arrangements of data displays as currently planned are as follows:

- Three GUI's for a damage control watch stander, which is a continuous watch station in all conditions of readiness.

- During emergency conditions, the same data projected on the DC watch standers GUIs will be fed through three projectors for display on a series of three large projection screens for the Damage Control Officers' (DCOs') use.

- The DC watch stander will control all necessary modifications, under the verbal direction of the DCO, to the ICS commands via a TRAK-BALL. The DCO will have control of the ship's automated combat readiness status via a separate TRAK-BALL adjacent to the DCO station.

- While variations are possible, current plans provide three GUIs/projections that will display information on each indicated screen as follows:

  1. Center: DCO Situation Awareness
     - Combat readiness status
     - High level ship plan, elevation and isometric views with color-coded casualty status
     - Multiple windows reflecting affected video compartment information
     - Response team – Commands and status

  2. Right: Compartment Level Details
     - Zoom-in graphics
     - Casualty status
     - Sensor data and status
     - Firemain, watermist, doors and ventilation commands and status

  3. Left: Sub-System Details
     - Firemain
     - Watermist
     - Early warning fire detectors (EWFD)
     - Door closure
     - Ventilation
     - Other available systems

- While the TRAK-BALL control of the GUI/projection screen will, due to battle dress requirements, be essential during combat conditions, routine steaming and in-port control of the ICS will offer use of the more user-friendly touch screen application. While, as previously pointed out, the ICS is an autonomous system, the TRAK-BALL and touch screen will provide for operator data augmentation or modification of orders to actuators. These orders may result from additional information made available from the rapid response team inputs, voice communications from other sources and video displays.

4.0 DESCRIPTION OF ICS DATA PROCESSING

The following scenario describes an example of ICS data processing in the event of a fire. In the event of a small or incipient fire, there is sensor information from the network indicating that general elements of fire exist in a space, which may include heat, obscuration or fire-generated gas analyses. In this event the information will be detected within the ICS Perception module. The Perception module-processed data then passes on to the Response module where the determination of appropriate action is made and orders are passed out to activate video in the affected area and if necessary the output interface to the network. In the case of this incipient fire, the IC is designed to alert (via an ethernet) a Rapid Response Team (RRT) to investigate and take appropriate manual action to control the situation. The results of these control actions will, in turn, be detected and reported to the IC in a closed-loop network that constantly processes compartment status information.

Should there be a progression of the incipient fire status, to a growing or fully involved fire, the IC would continue to process data from the sensors and/or messages from the RRT. This continuous fire data processing will result in operating commands within the ICS for appropriate activators to confine and control the fire. The activators operated would include ventilation, fire extinguishing systems, boundary cooling, and dewatering pumps all of which are, through the network, able to be controlled as necessary to provide maximum effort available to confine and control the fire. As the fire is brought under control and/or extinguished, the sensors will be continuously passing the fire status information to the IC which, in turn, will control the actuators until each one is returned to its' normal operating status.

This example of the ICS data processing is but one case that offers an insight to the practical control elements of a fire situation. The ICS is capable of processing data from many other casualty events that may be far more complex than this example.

4.1 DC-ARM MANNING ORGANIZATIONAL STRUCTURE

In a ship with reduced manning the personnel will, out of necessity, be more senior than the average crew of past ship designs. In addition, modern history has indicated an increase from the old three watch sections to as many as six sections while the ship is in-port. These variations in watch section rotation combined with the increased seniority of enlisted personnel overall has the prospect of increasing the total number of personnel required to maintain a sound automated

damage control casualty response capability. It is likely some control over the number will be maintained by use of a smaller number of watch sections in an at-sea environment while increasing to more sections while in-port.

In addition to watch station rotations, personnel will experience many other duties involving personnel management and training, routine house-keeping and essential maintenance. In order to maintain a professional focus, these additional duties should be closely related to the professional area of expertise and the associated watch station responsibilities. This consideration coupled with reduced rotation of personnel out of the ship class will promote a high state of professionalism.

The DC-ARM ICS manning is projected to include the following personnel:

- Senior Damage Control Officer (DCO) - This officer, due to possible elimination of the DCA, may be the engineering officer. The assigned individual will likely be a LCDR or, at least a senior LT. In a watch station environment, this individual and the major casualty investigators may rotate on the DCO watch station position.

- ICS Watch Standers - Will be Senior Petty Officers who rotate in the directed watch station.

- Security Watch/Roving Patrol/Rapid Response Investigators – These are mid-range to Senior Petty Officers, of which two are on watch during all underway periods.

- Major Casualty Investigators and Emergency Casualty Control Experts – These personnel are very senior Petty Officers who will be on call in the event of damage control requirements. These personnel would also be in a watch rotation with the DCO.

- Ship Maintenance and Casualty Repair Team – These personnel constitute a team of mid-range and senior Petty Officers, all under the charge of a Senior Chief Petty Officer. They perform damage control duties in an on-call capacity.

- Medical personnel will consist of an independent duty corpsman, plus a rated corpsman. Additional medical support would be provided by other crewmembers that would be trained in CPR and other aspects of emergency first aid.

4.2 ICS OPERATIONAL ENVIRONMENT

This ship's operational duties will define the ICS operational environment. These environments will result in variations of duty or watch sections and the number of personnel available for watch responsibilities. During in-port periods, the number of duty sections may well be increased over the number of watch sections at sea, resulting in a significant decrease in available watch standers. During the periods of at-sea routine steaming operations, the watch stander rotation should be stabilized at a balanced frequency that will provide for maintenance of

watch standing responsibilities, while providing adequate off-duty rest and opportunities for conducting other off-watch-duty responsibilities. During periods of high threat operations, the stabilized at-sea watch rotation would be maintained, but augmented by an increased readiness status for personnel from the major casualty investigators and casualty repair teams. In an increased readiness environment these personnel would be in an alert status that would provide for rapid deployment to damaged areas of the ship. During periods of casualty control or damage containment, the entire damage control contingent would be deployed to actively perform required casualty control duties. In the event of a mass conflagration that threatened loss of the ship, all ship's personnel would perform duties necessary to save the ship and/or provide for crew safety.

4.3 AVAILABLE ICS DAMAGE CONTROL HARDWARE AND CAPABILITY

There are many components that make up the ICS damage control hardware and watch space arrangement, which are unique to the DC-ARM ICS. The following is a description of overall hardware, spaces and primary DC functions of the components (Fig. 4).

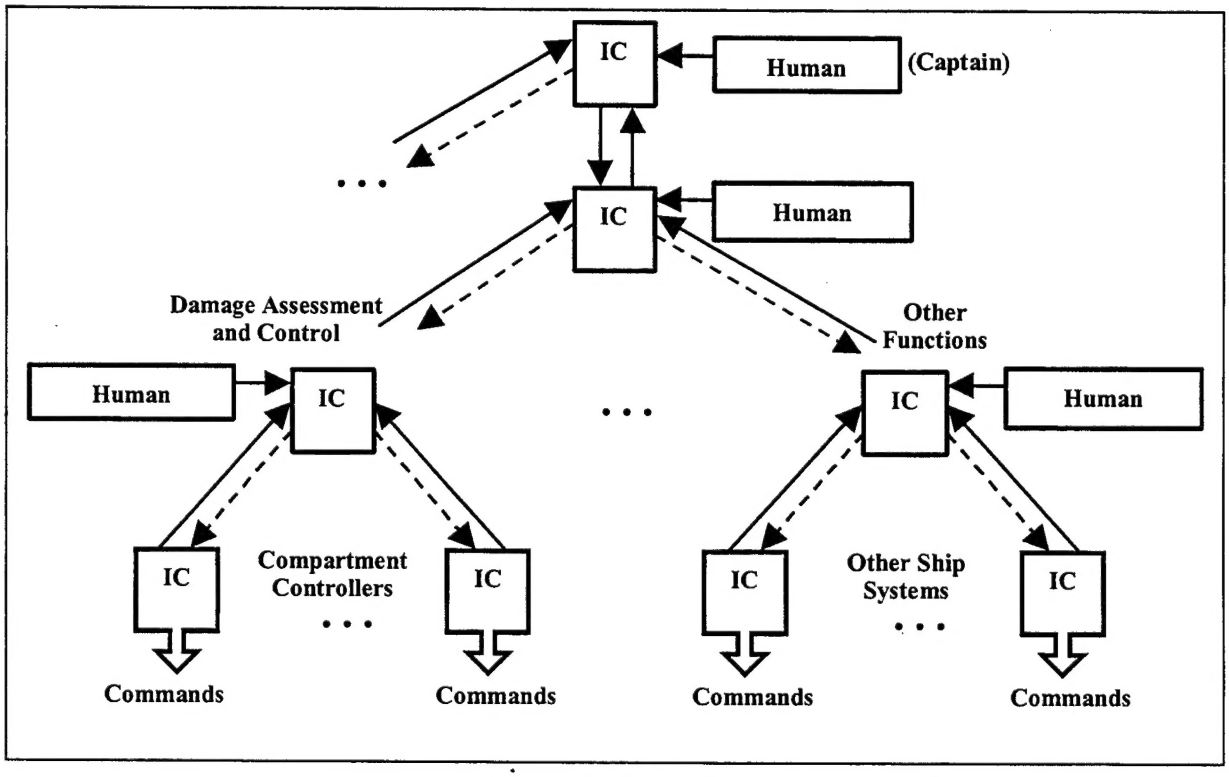

Figure 4. ICS Components

- Commanding Officer's (CO's) ship readiness status displays – This display provides the CO with a continuously updated status of the readiness state for each of the ship's primary mission areas. This readiness state is the result of processed ICS data that, during casualties, provide information regarding the impact of casualty damage on the various HM&E systems essential to the ship's combat readiness. This status display is in the form of monitors at the

various stations where the CO performs his duties. These stations may include the bridge, combat information center and the CO's stateroom.

- Primary DC Watch Station – The primary DC watch station will provide a complete arrangement of displays of ICS data to support the ICS watch stander and the Damage Control Officer. This arrangement will include all necessary communications and provide the ICS capability to exercise control over automated actuators. This watch station will be co-located with the ship's HM&E system control elements to provide for central control of all engineering elements of the ship's systems.

- Secondary DC Watch Station – The secondary DC watch station may be a direct duplication of the primary DC watch station, but located in a separate ship's zone from the primary station. It is essential that each of these stations be located at opposite ends of the ship and in a protected area on a lower deck, inside the skin of the hull.

- Zone-Distributed Intelligent Controllers – ICs would be distributed in numbers necessary to cover all damage control aspects of the subdivision zones within the ship. These ICs will all be under the control of a supervisor controller located in the damage control watch stations.

- Zone-Distributed Emergency DC Equipment – In view of the lack of the previously utilized repair party concept, there is no longer a need for repair lockers. Therefore, the equipment previously stowed in lockers will be distributed throughout the ship [7] with consideration given to equipment required relative to the design of each unique zone. The amount of equipment within each zone must be adequate to support the capability of DC personnel who may be involved in confinement of the casualty or damage.

- Primary Battle Dressing Station – This station must be a fully contained and equipped facility to support routine and emergency personnel medical needs of the crew. This facility should, like the DC Watch Station, be located within the protected confines of the hull and in a zone at the opposite end of the ship from the Secondary Battle Dressing Station. This station is considered the routine work area and watch station for an independent duty corpsmen during any condition that may be a threat to crew members.

- Secondary Battle Dressing Station – This station, within a zone in the opposite end of the ship from the Primary Battle Dressing Station, will be equipped as an emergency fallback medical station. This station will be provided with adequate supplies to support needs of the crew in the event the Primary Battle Dressing Station is lost. In high threat conditions, the rated corpsmen and/or other first-aid-trained personnel will be stationed in this facility.

- Communications – The primary ICS means of communications to all DC personnel on watch will be via data-linked information to and from the ICS. This data link will provide a two-way data flow initiated by either the automated features of the supervisory IC or the team leader of the RRT, casualty investigators and/or the casualty repair team. The

communications between the DC watch stander and Damage Control Officer will be voice. The DCO will have access to the ship's general announcing system (1MC) and the engineering announcing system (21MC) to broadcast necessary general knowledge information. Although not a primary means of communication, the application of DC WIFCOM will be available as a backup RF Link between all DC personnel.

4.4 ICS OPERATIONAL PROCEDURES

- In-port procedures would involve a continuous DC watch at the ICS watch station and a continuous single individual on security/roving patrol watch. This security watch would rove the established key-registering clocked watch station positions, requiring patrol throughout the ship. This watch individual would continuously move about the ship during the assigned watch rotation. The DCO position would be filled by the Engineering Duty Officer (EDO). In the event of an in-port emergency, the EDO would man the DCO position and, via the ICS watch stander, exercise control over the ICS effort to control the casualty event. When a casualty occurs, personnel from the Engineering Department would report to the EDO/DCO for assignment to duties as casualty investigators, controllers and support for personnel casualty treatment.

- During an at-sea routine steaming environment, there would be a continuous ICS watch and two security watch standers/roving patrols on continuous watch. The security watch standers would individually patrol clocked watch stations throughout the ship in a separated method that will provide for continuous and frequent coverage of the entire ship. In the event of an emergency, the on-call casualty investigators and control experts will be deployed as directed by the DCO. In this routine steaming environment, the DCO watch will be augmented by the most senior enlisted personnel from the ship maintenance and casualty repair team. Should a casualty occur that was not immediately brought under control, the maintenance and casualty repair team and medical personnel would be deployed to contain and control the casualty and provide medical assistance as necessary.

- In high threat operations, the procedures would be similar to those in the at-sea routine, but the major casualty investigators and the casualty repair team would be in an alert status, distributed about the ship, ready to react on short notice as directed by the DCO.

- During casualty management operations, all personnel will be deployed as directed by the DCO to contain, control, overhaul the casualty, and investigate as necessary to provide the DCO and CO with information regarding any impact to the ship's readiness status.

4.5 PERSONNEL DUTIES AND RESPONSIBILITIES

- The Damage Control Officer's duties involve total management control over the ICS, damage control personnel and the control and containment of all DC casualties within the ship. He is responsible to ensure all damage control activities are properly executed.

- The ICS Watch Stander's duties are to maintain a continuous watch over the ICS, manipulate the screens as directed by the DCO or in the DCO's absence, ensuring the proper screens are available to convey the detailed status of the ship and casualties. Each watch stander is responsible for the proper exercise of control over the ICS and carrying out directions of the DCO.

- The Security Watch/Roving Patrol Watch Standers are responsible for maintaining security within the ship. They will document maintenance requirements and act as rapid response investigators, taking corrective action for any casualty or suspected casualty that may be discovered by them. In this capacity, they may be directed by data from the ICS or by the DCO.

- The major casualty investigators and emergency control experts are responsible for assisting in investigations of any and every casualty in order to provide the CO and DCO with the casualty effects on the ship's primary mission, emergency personnel evacuation requirements and critical repairs essential to the ship and crew safety.

- The ship's maintenance and casualty repair teams shall be responsible to augment any ongoing casualty damage control effort as directed by circumstances or by the DCO. Following any major casualty or battle damage investigation this team would be directed to assist in removing and management of personnel casualties, then proceed to conduct emergency casualty correction. For electronic casualty correction purposes, at least one of these repair teams, in the absence of the former Repair VIII, should be capable of conducting electronic casualty correction. This electronic specialist would be a casualty correction team member, above and beyond a systems operator assignment.

- Medical Personnel, in addition to routine medical treatment of the crew, are responsible for maintaining and manning the Primary and Secondary Battle Dressing Stations. The corpsmen, during any emergency or casualty, shall be prepared to treat and/or assist in directing non-medical personnel in treatment of other injured crewmen. They shall assist in the establishment of triage arrangements and evacuation of personnel as required and/or directed.

4.6 OPERATIONAL CONDITIONS OF READINESS MANNING

- In a reduced manned ship, the previously used conditions of readiness manning will be modified to provide for maximum efficiency in utilization of personnel. The in-port readiness state may be established for a far fewer number of personnel to handle emergency conditions including getting underway than were previously required. It is likely that as little as one sixth of the crew will be capable of getting a ship underway and/or managing emergency actions that may be required. This capability will be provided for through automation of systems that, in the past, were manpower-intensive.

- At-sea routine steaming will likely constitute about 20 percent of the crew on watch at any given time in a four-section watch rotation. The remaining 20 percent of the crew will be non-standing watch personnel who are providing service support for the entire crew.

- During periods of high threat operations, the manning of watch stations will be similar to the at-sea steaming routine. The exception will be that personnel, such as DC major casualty investigators, and the maintenance and casualty repair teams will be in an alert status that will support a rapid response to any damage or casualty.

- During periods of actual combat, the entire crew would be at full readiness on their particular watch stations, ready to conduct any and all combat-related duties. This manning approach would ensure distribution of personnel to prevent mass casualties in the event of a weapons hit. It will also provide for an alert response from the crew in the event of mass conflagration. Crew numbers will be reduced to 25 to 30 percent of previous ship's crews and continue to provide adequate conditions of readiness. These numbers will also offer far less personnel assignment flexibility than has existed in the past.

5.0 TOTAL MANNING REQUIREMENTS

Tables 1 and 2 outline the probable personnel assignments necessary to support the damage control organization in a ship equipped with the ARL/SST DC-ARM ICS. The Tables are intended to reflect the assignments relative to the varying conditions of readiness and number of watch stations established:

Table 1	AT-SEA OPERATIONS MANNING		
Manned Position	Number of Watch Sections		
	3	4	5
DCO	1 Watch Section Augmented by Senior PO's From Maintenance and Repair Team	1 Watch Section Augmented by Senior PO's From Maintenance and Repair Team	1 Watch Section Augmented by Senior PO's From Maintenance and Repair Team
ICS Watch Standers	3	4	5
Security Watch/Roving Patrol	6	8	10
Major Casualty Investigators/Casualty Control Experts	2	2	2
Ship Maintenance and Casualty Repair Team	6	6	6
Medical Personnel	2	2	2
TOTAL PERSONNEL REQUIRED	**20**	**23**	**26**

Table 2	PERSONNEL BILLET ASSIGNMENT BY RANK	
Position	Number	Rank
DCO	1	LCDR
ICS Watch Standers	3 to 5	First Class PO's
Security Watch/Roving Patrol	6 to 10	Second and First Class PO's
Major Casualty Investigators And Casualty Control Experts	2	Chief Petty Officers
Ship Maintenance and Casualty Repair Team	1 5	Senior CPO Leader First and Second Class PO's
Medical Personnel	2	HMC and HM2
TOTAL	**20 TO 26**	

These ICS-assigned personnel may be augmented by additional HM&E watch standers in a primary engineering control room environment that would have machinery operators in addition to damage control personnel.

5.1 REDUCED MANNING IMPACT ON MAINTENANCE

As previously discussed, shipboard maintenance as it is known today in Levels 1, 2, and 3 for either conduct of the maintenance or management associated with Level 3 will not be practical. While the need for emergency repairs will be a constant requirement, the operational watch standing requirements, training and housekeeping duties for a reduced crew will utilize most of the available time. The off-duty periods beyond crew rest often will involve equipment inspections and documentation of future required maintenance.

In view of the lack of Levels 1, 2, and 3 ship maintenance capability, maintenance that is now routinely accomplished or managed in most ships, there must be a substantial repair and maintenance facility/capability established ashore to support ongoing equipment maintenance and repair requirements. This shore-based maintenance effort is required to offset the maintenance-driven need for the large crew that exists in today's ships. Such a maintenance facility, similar to the Ship Intermediate Maintenance Activities (SIMA's) of today, should be focused on the maintenance needs relative to the reduced manning concept. This approach should be ship class oriented, which would simultaneously provide personnel training to meet the various ship-oriented technical requirements and provide the associated promotions necessary to ensure availability of the senior petty officers required to man the ICS-automated ships.

The previously discussed manning consideration requires a fully ICS-automated damage control system equal to, or more capable than, the planned Penn State ARL ICS. This automated system will eliminate the current repair party/locker concept. Emergency handling equipment will be required but must be distributed throughout the ship, vice co-located with a repair party/locker. While this proposed manning consideration has a strong potential for application in future automated damage control ships designed for reduced manning, it also provides for emergency maintenance of ship's warfighting operational readiness. The proposed damage control manning

That is required but must be distributed throughout the ship, vice-co-located with a repair party/locker. While this proposed manning consideration has a strong potential for application in future automated damage control ships designed for reduced manning, it also provide for emergency maintenance of ship's war fighting operational readiness. The proposed damage control manning would constitute a total of 20 to 26 personnel, one of which is an officer, while all others are chiefs and mid-range to senior petty officers. This experienced organization, in company with the ICS automation, will be capable of hull and system maintenance of an emergency nature, casualty and battle damage control. Those repairs beyond that necessary for crew and ship safety would have to be accomplished in-port/ashore. With these achievements relative to ICS development, installation and shore-based maintenance, the potential manpower reduction over current-day shipboard damage control manning requirements will be significant.

6.0 SUMMARY

The ICS is a technically proven autonomous automation system that, in company with trained personnel, will provide for a significant reduction in overall damage control personnel requirements. The system is reliable to the extent it will operate in harsh environments, even when some zone IC components may be damaged. The ICS system maintenance requirements are minimal and the system is relatively inexpensive. The programmability of the system will allow for ship modifications/updates ensuring continued reliable application. While the system will replace personnel, it will also require increased seniority among enlisted personnel and the accompanying increase in training.

7.0 REFERENCES

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